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Effects of Mixing Time and Emulsifier on Yellow Layer Cakes Containing Butter

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The United States in 1971 removed an estimated 340 million pounds of butter from the commercial market (1). Surpluses of about this magnitude have existed for many years. In an effort to find more or improved usage for this fat, an investigation was made into some factors affecting the baking quality of butter in yellow layer or sheet cakes.

When butter is used as a shortening in cakes it produces desirable rich flavor (2, 3) and tenderness (3, 4) in the finished product. However, these desirable qualities are usually accompanied by undesirable low cake volume. The addition of emulsifiers can increase the volume of butter cakes (5, 6). As some bakers use part butter and part vegetable shortening in their cakes formulas (7), it was thought worthwhile to compare the baking quality of cakes containing a 50/50 blend of butter and shortening with that of cakes containing butter (with and without added emulsifier), and also to compare the baking quality with that of cakes made with commercial cake shortening (CS). As no known data are published concerning the effect of mixing time on butter cakes, this effect was also investigated. For these purposes a factorial study was made in which types of shortenings or fats, emulsifier level, and mixing times were varied.

Materials

A commercial bleached cake flour containing 8.0 per cent protein and 12.5 per cent moisture was used.

Whole eggs from one lot of commercially pasteurized and frozen material were thawed, sealed in cans in two-pound lots and refrozen at 5°F. They were then brought to room temperature before use each day.

Butter was manufactured in the Dairy Products Laboratory from 40 per cent fat-containing sweet cream pasteurized at 165°F for 30 minutes. After the cream was cooled to 50°F and held for 24 hours it was churned at 52°F in a 50-gallon stainless steel churn. Salt was then mixed into the butter. It was next frozen and stored at 5°F. Before being used, it was thawed overnight at room temperature. The butter contained 86 per cent fat, 10.5 per cent moisture, 1.5 per cent salt, and 2.0 per cent curd.

A blend of equal parts of two commercial emulsifiers (Atmul 80 and Atmul 84)[1] were used in cakes. Previous studies showed that the 2.5 per cent level of emulsifier (basis flour) was as effective as the 5.0 per cent blend in producing a good quality cake.

Spray-dried, low-heat, non-fat dry milk was prepared in the Dairy Products Laboratory. The fluid milk to be used was heated to 145°F for 30 minutes before being condensed and dried.

[1] Mention of brand or firm names does not constitute an endorsement by the Department of Agriculture over others of a similar nature not mentioned.

Table I

Yellow Layer Cake Formulas

Cream Sugar Shortening			Blend Flour Shortening		
Ingredient	**%**	**Method**	**Ingredient**	**%**	**Method**
Sugar	115	Cream 5 min. (2nd speed)	Flour	100	Cream 5 min. (2nd speed)
Fat	50		Fat	50	
Eggs, whole	55	Add to sugar-shortening	Sugar	115	
Vanilla	1 tsp	Mix ½ min. (2nd speed)	Baking powder	6	
			Salt	2.5	Sift together
Flour	100	Add sifted dry ingredients			
Baking powder	6	alternating with milk solution	Skim milk solids	14	Add half solution to dry
Salt	2.5		Water	81	ingredients
					Add flour and shortening
Skim milk solids	14				and mix 2 min.
Water	81				(1st speed)
		Mix 1 min. (1st speed)			
		2nd min. (variable speed)	Eggs, whole	55	Add, plus rest of milk
			Vanilla	1 tsp	solution
		Batter temperature 72-75 F.			Mix variable speed
		Scale 370 g. batter			
		Bake 365° 25 min.			

Methods

Baking and physical testing were conducted in an air conditioned room at 74-78°F. Batter temperatures were controlled at 71-74°F.

Baking. The baking methods used are covered in **Table I.** The creaming of sugar and shortening was the procedure used for the most part in this study. All shortening was used on a 50 per cent fat-to-flour basis. To bring the salt and absorption levels in the batter to a fixed level, compensations for the moisture and salt in the butter were made. Butter and shortening were brought to room temperature and then creamed with sugar. These blends were held no longer than four days before use. Emulsifiers, when used, replaced an equal amount of shortening in the formula.

Specific Volume: Specific volume is expressed in cc cake volume/g of cake. Volume was measured by rape-seed displacement.

Cake Height: The cake height in mm was determined by placing a marked template over the surface of a cut half of cake and measuring the center height and the heights of cake 6 cm from the middle on each side. The sum of these three heights is the cake height given in this report.

Cake Scoring: The following numerical values were assigned to various cake qualities. Ten points each were assigned for the best symmetry, crumb color, crust color, and grain. A score of 20 was assigned for ideal texture—one that is soft, velvety, and yet resilient. The crust color of butter cakes is golden brown, and this color crust was scored highest. Cakes with commercial shortening have a dull brown color which was rated lower. As the crumb color of butter cakes is more yellow than that of cakes with commercial shortening, crumb color was judged to a large extent on brightness.

Mobile Fat: Mobile fat values were determined on 2-inch diameter cut circles of cake crumb of 1-inch thickness based upon the method described by Townsend *et al.* (8). Samples were placed on sheets of standard laboratory paper toweling, covered with a 2-inch diameter piece of sheet metal, weighted down with 140-g weights and held 16 hours at 98°F. The oil was expressed on paper and appeared as a circular spot, the diameter of which was measured. From this the area of the spot was computed. The results are expressed in cm^2. The technique measures degree of oiliness of cake placed under slight to moderate pressure. Oiliness is believed to be a good indication of cake eating quality (8). The rich tasting all-butter cakes have high mobile fat values.

Organoleptic Evaluation: Cakes were judged by 10 to 20 members of the Dairy Products Laboratory (DPL) by using the nine point he-

Table II

Significance of F Ratios for Main Effects and Their Interactions

Ingredient or Treatment	Degrees of Freedom	Specific Volume cc/g.	Heights mm.	Total Score	Specific Gravity	Viscosity Centipoise	Compressimeter g. to depress 1 mm.	Mobile Fat cm^2 of expressed fat
Fats (F)	2	**	**	**	**		**	**
Emulsifiers (E)	1	**	*		*		**	**
Mixing times (M.T.)	2							
M.T. × F	4	**			**			
M.T. × E	2			*				
E × F	2	**	*					**
Days	5						**	
Error Mean Square		.013	17.48	0.372	.00037	30	7.25	16.74
Std. Deviation (for compressimeter)		.114	4.18	.61	.0192	5.47	2.7	4.09

* Significantly different at the 5% confidence level.
** Significantly different at the 1% confidence level.

donic scale (9). Fresh slices of whole cake, two to four hours old, were evaluated for both taste and texture. The samples were randomly presented to panelists in individual booths under amber lights. Tasters were provided with rinse water at 25°C to use between samples. The data were statistically treated (10).

Firmness Studies: The Baker compressimeter was used to determine firmness. Compression was determined by using the No. 2 setting of fulcrum on the cakes; it is expressed as the gram-load required to depress a slice of cake 1 mm. One inch-thick slices of cake crumb, 2.5-inch square, were cut by using a mitre box to make a uniform thickness cut. Cakes were stored for one, two, three, four, and five days in a tightly closed cabinet at room temperature before being sliced.

Specific Gravity: Specific gravity was determined by weighing batter fresh out of the mixer at 72-75°F into a plastic cup and comparing its weight with that of water held by the cup.

Viscosity: Viscosities of freshly mixed batter were determined by using a Haake Rotovisco[1] viscosimeter equipped with the standard measuring system, Model MV I. The spindle in the cup, rotating at 76 sec^{-1}, was used in all measurements. As all fluids studied were non-Newtonian and exhibited small decreases in viscosity on stirring, readings were taken at zero, two, and five minutes after the initial stirring and averaged. All samples were held at 30°C during viscosity measurements. Measurements were expressed in centipoises.

Results and Discussion

A statistically designed study with three types of fats, three mixing times, and two levels of emulsifier was made. Two cakes were made from each batter. As two batters were made, a total of four cakes for each factor were baked.

F Ratios: Significant F ratios of fats and emulsifiers and of mixing times, and some of their interactions are indicated in **Table II** at both the 5 per cent and 1 per cent levels of confidence. Each of the main effects of fats represents averages of cakes at all mixing speeds and with and without emulsifier.

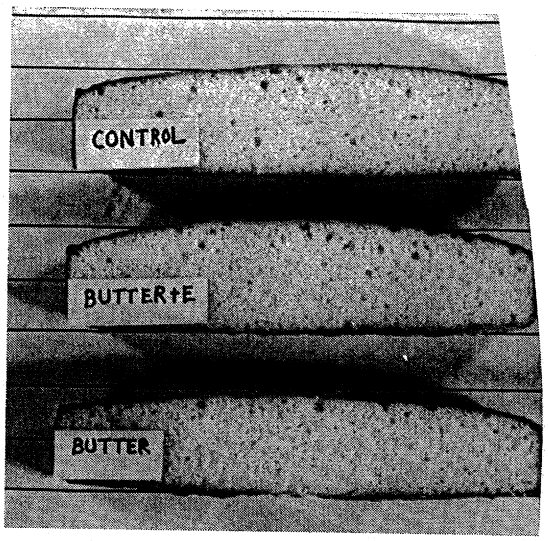

Figure 1: ***Effect of emulsifier on butter cakes at 3-minute mixing time.***

Table III

Average Cake Quality Values for Different Fats

Treatment	Specific Volume	Heights	Total Scores	Specific Gravity	Compressimeter	Mo F
Cake shortening	3.44	125.2	51.04	0.879	18.95	2
50/50 Blend cake shortening and butter	3.46	129.2	51.83	0.854	15.99	4
Butter	3.35	123.0	53.17	0.823	15.09	7

Table IV

Average Quality Values of Cakes With and Without Emulsifier

Treatment	Specific Volume	Height	Specific Gravity	Compressimeter	Mo
None	3.36	123.9	0.862	15.89	5
2.5%	3.48	127.6	0.842	17.46	4

Table V

Interaction of Fats and Emulsifiers (E) on Specific Volume, Height and Mobile Fat Values of Cakes

	Specific Volume		Height		Mobile F	
Treatments	0% E	2.5% E	0% E	2.5% E	0% E	2.5
All cake shortening	3.42	3.46	126	124.3	28.9	2
Half cake shortening/ half butter	3.43	3.50	127.5	130.8	47.0	3
All butter	3.23	3.48	118.3	127.7	82.0	6
Significant difference at 5% level	0.10		3.6		9.3	

Effect of Type of Fat: The type of fat used in cakes produces significant differences in cake quality scores. **Table II** shows the significant F ratios for main effects and their interactions. **Table III** shows that butter produces cakes of lower specific volume and height than those made with either cake shortening (CS) or a 50/50 blend of CS and butter. However, because of the softening effect of butter on texture and the improving effect on crust color and eye appeal, cakes made with butter show the highest cake quality score rating. Although a specific gravity of the batter is g erally associated with cakes of h er volume, the effect of fat t modifies this. Butter produces a c with the lowest specific gravity. E ter also produces cakes with highest mobile fat score which flects the ease of release of fat the cake by touch or moderate pr sure. With the exception of cc pressimeter values, other qua values for cakes containing a bl of equal parts CS and butter more like those of the cakes c

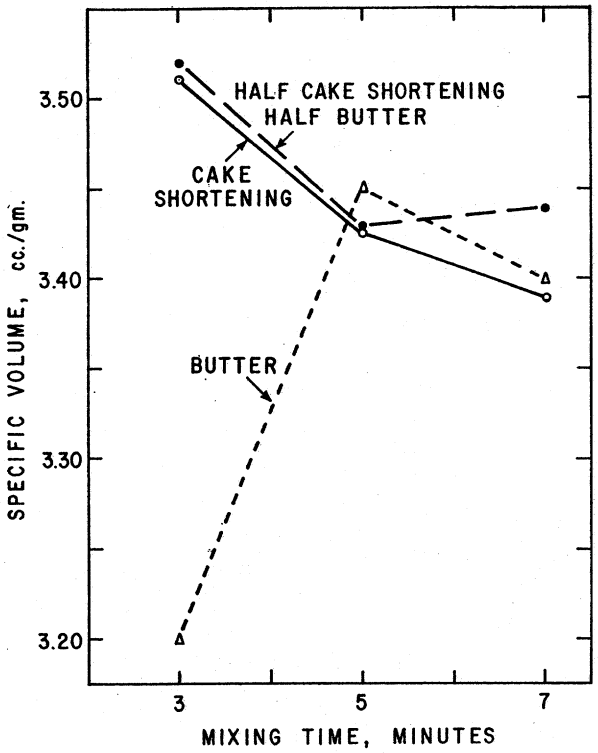

Figure 2: *Interaction of mixing times and fats on cake specific volume.*

Table VI

Comparison of the Panel Acceptability of Cakes Containing Butter or Commercial Cake Shortening on 50% Fat/Flour Basis

	Butter		Commercial Cake Shortening	
	Flavor	Texture	Flavor	Texture
No. 1	6.95	7.06	6.85	6.48
No. 2	7.40$\underline{S}_1$	7.23$\underline{S}_2$	6.60S_1	6.23S_2
No. 3	7.25$\underline{S}_3$	6.90$\underline{S}_4$	6.50S_3	6.00S_4
Average 3 panels	7.20	7.08	6.65	6.24

$\underline{S}$ = Significantly preferred at 5% confidence level

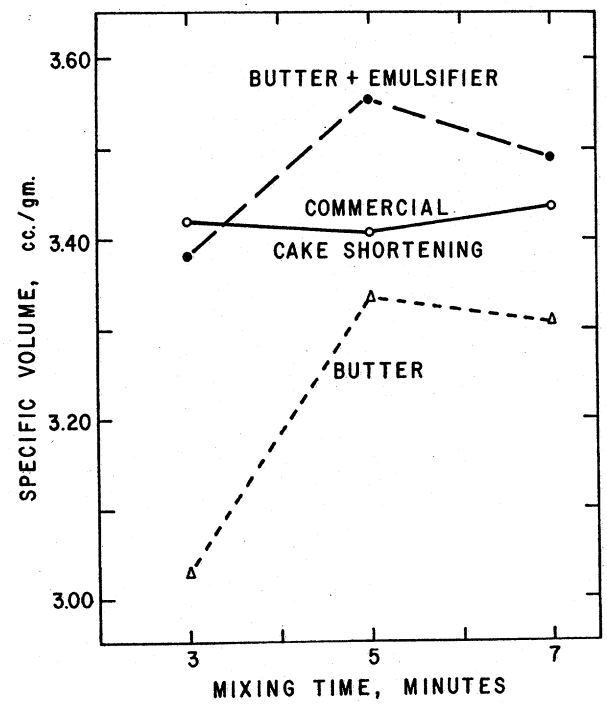

Figure 3: *Effect of emulsifier addition to butter on cake specific volume.*

taining CS than butter.

Effects of Emulsifier: Addition of 2.5 per cent emulsifier to cakes with three types of shortening significantly changed the quality indices of the cakes. **Tables II** and **IV** show that emulsifier significantly increases the average values of specific volume, cake height, and firmness or compression of cakes. It also decreases cake mobile fat values (probably by stabilizing the fat particles so they resist leaking from their matrix under force or pressure). By interaction, emulsifier significantly increases the volume and the cake height **(Table V)** in cakes containing butter but not those made with CS or a blend of CS and butter. Emulsifier also significantly decreases mobile fat values in cakes containing butter. It is realized that this difference is probably because CS already contains emulsifier which functions to increase volume and height and decrease mobile fat values even in cakes made with the blend of shortenings. Thus, the effects of additional emulsifier aren't so evident. **Figure 1** shows a picture of the effect of emulsifier on butter cakes and compares the volume of the butter cakes with that of the control cake made with CS. Note the improved height or volume of center slices of cake made with butter to which emulsifier was added.

Effect of Mixing Time: Although no statistically significant differences in quality indices of cakes as a function of batter mixing times were noted when three different shortenings and two emulsifier levels for each mixing time were averaged, significant interactions were observed. **Figure 2** shows that increasing the mixing time of batters containing butter from three to five minutes significantly increases the specific volume of their cakes. Mixing causes no significant change in the specific volume of cakes with other shortenings. The significant increase in volume of cakes by extending the mixing times of batters (up to five minutes) containing butter with no emulsifier is especially pronounced, as shown in **Figure 3.** Less increase in cake volume due to increasing the mixing time is observed with batters containing butter in the presence of emulsifier.

Extended mixing of batters con-

Table VII

Effect of Shortening Composition on Panel Acceptability of Cakes

	Day	Flavor	Texture	Average Flavor	Average Texture
Cake shortening (CS)	1	6.5S_1	6.00S_2	6.62	6.24
	2	6.85	6.48		
50/50 blend of butter and CS	1	6.85	6.60	6.80	6.32
	2	6.75	6.05		
Butter	1	7.25$\underline{S}_1$	6.90S_2	7.10	6.98
	2	6.95	7.06		
Butter—emulsifier	1	7.25	7.05$\underline{S}_2$	7.25	7.05

$\underline{S}$ = Significantly preferred at 5% confidence level

mercial shortening with butter in cakes with or without emulsifier increased their flavor and significantly increased their texture scores. Those properties of cakes containing a blend of half butter and half CS tended to match those properties of the cakes containing all CS more closely than of cakes containing only butter as shortening. Therefore, to produce a superior quality cake, all of the shortening should be butter.

Table VIII

Effect of Method of Cake Mixing on Panel Acceptability

Minutes	Cream Sugar Shortening: Butter				Cream Sugar Shortening: Commercial cake shortening		Blend Flour Shortening: Butter				Blend Flour Shortening: Commercial cake shortening	
Mixing time	Day 1 Flavor	Day 1 Texture	Day 2 Flavor	Day 2 Texture	Day 2 Flavor	Day 2 Texture	Day 1 Flavor	Day 1 Texture	Day 2 Flavor	Day 2 Texture	Day 2 Flavor	Day 2 Texture
3	6.90	7.10	—	—	6.60S_1	6.23S_2						
7	6.80	6.70	7.40$\underline{S}_1$	7.23$\underline{S}_2$	—	—						
2							6.60	7.10			6.12S_1	5.30S_2
5							7.05	7.40	7.30$\underline{\underline{S}}_1$	7.00$\underline{\underline{S}}_2$		

$\underline{S}$ = Significantly different at 5% confidence level

$\underline{\underline{S}}$ = Significantly different at 1% confidence level

taining butter causes changes in cake quality indices which are small but appear to be accentuated by the addition of emulsifier. Many of the changes are not significantly different.

Extended mixing increases cake volume; addition of emulsifier brings about a larger increase. The extended mixing of batters containing butter only slightly increases cake compressibility, decreases cake mobile fat values, and decreases the specific gravities of the batter. Addition of emulsifiers at each mixing time produces significant changes in these indices in the same direction. With extended mixing, the crust may also become drier and duller looking; these conditions are accentuated by the addition of emulsifier.

Panel Studies: **Table VI** shows that butter cakes rate higher in both taste and texture than cakes containing CS. In two out of three panels the butter cakes were rated as significantly better than the cake with CS in both taste and texture. **Table VII** shows that the addition of emulsifier to butter does not change its high panel rating for both taste and texture. This is observed even though emulsifier increases the compressimeter firmness of the cake. Replacement of half of CS with butter does not significantly affect the panel scores of the cake. Its panel rating more closely matches that of the cake containing CS than butter.

As the order of blending ingredients may influence the panel acceptability of product, this factor was also investigated. **Table VIII** shows that the blending of flour and shortening initially is as satisfactory a mixing method for butter cakes as is the method of creaming the sugar and shortening. However, the use of CS in cakes made by first blending sugar and flour is not as effective as when the sugar and shortening are creamed.

Conclusions

Sweet cream butter when used as shortening in yellow layer cakes lowered volume to 5 to 10 per cent below that of cakes made with commercial shortening, but produced significantly better over-all cake quality scores than did CS. Increasing the mixing time (up to five minutes) of batters containing butter significantly improved the volumes of their cakes. Addition of emulsifier to butter in cakes produced volumes comparable to or better than those of cakes made with CS, and produced superior quality scores at all mixing times of the batter. Compressimeter tests showed that butter shortening with or without emulsifier produced softer cakes than did commercial shortening initially and through five days' storage at room temperature. Replacement of com-

Acknowledgement is made to E. L. Ayers for baking the cakes.

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